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Tongue River Reservoir, Big Horn County, Montana

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

May 77

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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Report
on
Tongue River Reservoir
Big Horn County
Montana
EPA Region VIII
Working Paper No. 803

With the cooperation of the
Montana Department of Health & Environmental Sciences
and the
Montana National Guard
May, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(a)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General John J. Womack, the Adjutant General of Montana, and Project Officer Major William Yeager, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS
STATE OF MONTANA

LAKE NAME	COUNTY
Canyon Ferry	Broadwater, Lewis and Clark
Clark Canyon	Beaverhead
Flathead	Flathead, Lake
Georgetown	Deer Lodge, Granite
Hebgen	Gallatin
Koocanusa	Lincoln, MT; British Columbia, Can.
Mary Ronan	Lake
McDonald	Flathead
Nelson	Phillips
Seeley	Missoula
Swan	Lake
Tally	Flathead
Tiber	Liberty, Toole
Tongue River	Big Horn
Whitefish	Flathead
Yellowtail	Carbon, Bighorn, MT; Bighorn, WY

TONGUE RIVER RESERVOIR

STORET NO. 3014

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Tongue River Reservoir is eutrophic. It ranked fourteenth in overall trophic quality when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six water-quality parameters*. All of the other water bodies had less median total phosphorus, eight had less median dissolved orthophosphorus, five had less and three had the same median inorganic nitrogen, and all of the others had less mean chlorophyll a and greater mean Secchi disc transparency. Marked depletion of dissolved oxygen with depth occurred at station 1 in May.

B. Rate-Limiting Nutrient:

Due to significant changes in nutrient levels during shipment of the samples from the field to the laboratory, the algal assay results are not considered representative of conditions in the reservoir at the times the samples were taken.

The reservoir data indicate nitrogen limitation at all sampling stations and times, with the exception of station 1 in October.

C. Nutrient Controllability:

1. Point sources--The wastewater treatment plant at Sheridan,

* See Appendix A.

Wyoming accounted for the entire point source load, contributing 11.1% of the total phosphorus input to Tongue River Reservoir during the sampling year.

The present phosphorus loading of 9.44 g/m^2/year is nine times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11), and point-source phosphorus control alone probably would not result in any significant improvement in the existing trophic condition of the reservoir.

2. Non-point sources--Non-point sources accounted for 88.9% of the total phosphorus load during the sampling year. The Tongue River contributed 75.4%, and ungaged minor tributaries and immediate drainage contributed an estimated 13.3%.

In a previous report, it is noted that agriculture is the major water use in the drainage basin (Pulzin, 1974). Water is diverted for the irrigation of about 260 km^2 above the reservoir (Anonymous, 1974). It appears that improvement in the trophic quality of this water body could only result from control of nutrients in agricultural runoff as well as in point-source discharges within the drainage. Further study is needed to determine the controllability of non-point nutrients and to also determine the impact of mining operations in the area which could further degrade the quality of this water body.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 14.15 kilometers².
2. Mean depth: 6.1 meters.
3. Maximum depth: 27.7 meters.
4. Volume: 86.315 x 10^6 m^3.
5. Mean hydraulic retention time: 78 days (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Tongue River	3,825.4	14.15
Leaf Rock Creek	59.6	-
Minor tributaries & immediate drainage -	685.2	-
Totals	4,570.2	14.15

2. Outlet -

Tongue River	4,584.3**	12.83

C. Precipitation***:

1. Year of sampling: 50.7 centimeters.
2. Mean annual: 40.3 centimeters.

† Table of metric conversions--Appendix B.
†† Norpestad, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Tongue River Reservoir was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one or more depths at three stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the May and October visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 16.2 meters at station 1, 9.1 meters at station 2, and 3.8 meters at station 3.

The sampling results are presented in full in Appendix B and are summarized in the following table.

[illegible] SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR TRIBUTARY STREAM [illegible]

	1ST SAMPLING (5/23/75)			2ND SAMPLING (6/19/75)			3RD SAMPLING (7/15/75)		
	3 SITES			3 SITES			3 SITES		
PARAMETER	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	9.3 - 12.6	11.4	11.3	19.6 - 23.7	21.4	21.2	9.8 - 11.4	10.8	10.9
DISS OXY (MG/L)	7.4 - 10.4	8.7	8.8	4.2 - 9.4	6.5	6.8	8.8 - 11.4	9.7	9.8
CNDCTVY (MCMHO)	280. - 520.	407.	425.	480. - 780.	540.	587.	410. - 650.	535.	555.
PH (STAND UNITS)	8.3 - 8.7	8.5	8.6	8.4 - 9.0	8.7	8.8	8.6 - 8.9	8.4	8.4
TOT ALK (MG/L)	134. - 244.	188.	182.	154. - 256.	186.	197.	242. - 332.	284.	284.
TOT P (MG/L)	0.039 - 0.241	0.095	0.059	0.062 - 0.249	0.072	0.051	0.038 - 0.232	0.083	0.042
DFLD P (MG/L)	0.006 - 0.037	0.017	0.015	0.007 - 0.018	0.011	0.009	0.003 - 0.017	0.009	0.004
NO3-NO2 (MG/L)	0.328 - 0.578	0.394	0.345	0.228 - 0.325	0.276	0.255	0.228 - 0.479	0.308	0.268
AMMONIA (MG/L)	0.029 - 0.428	0.175	0.045	0.023 - 0.038	0.031	0.031	0.029 - 0.059	0.033	0.032
KJEL N (MG/L)	0.588 - 1.400	0.789	0.658	0.468 - 1.288	0.699	0.668	0.468 - 0.868	0.595	0.598
DISS N (MG/L)	0.850 - 0.982	0.914	0.898	0.848 - 0.958	0.941	0.941	0.941 - 0.976	0.951	0.959
TOTAL N (MG/L)	0.928 - 1.946	1.314	1.228	0.428 - 1.233	0.788	0.829	0.428 - 0.828	0.546	0.559
CHLOPHYL A (UG/L)	7.3 - 11.2	9.4	9.3	25.8 - 35.4	29.4	28.9	4.8 - 24.5	15.8	15.9
SECCHI (METERS)	0.4 - 1.1	1.0	1.1	0.2 - 0.6	0.4	0.5	0.2 - 0.4	1.0	0.4

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera		Algal Units per ml
05/23/75	1.	Chroomonas sp.	2,447
	2.	Euglena sp.	1,106
	3.	Cryptomonas sp.	804
	4.	Stephanodiscus sp.	737
	5.	Asterionella sp.	166
		Other genera	269
		Total	5,531
08/29/75	1.	Euglena sp.	946
	2.	Gymnodinium sp.	908
	3.	Chroomonas sp.	670
	4.	Stiptococcus sp.	416
	5.	Asterionella sp.	378
		Other genera	794
		Total	4,312
10/15/75	1.	Stephanodiscus sp.	870
	2.	Cryptomonas sp.	591
	3.	Fragilaria sp.	552
	4.	Chroomonas sp.	197
	5.	Navicula sp.	116
		Other genera	364
		Total	2,482

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
05/23/75	1	7.3
	2	11.2
	3	7.3
08/29/75	1	16.9
	2	20.5
	3	38.6
10/15/75	1	20.5
	2	24.5
	3	4.9

C. Limiting Nutrient Study:

The algal assay results are not considered indicative of conditions in the reservoir at the time the samples were collected (05/23/75 and 10/15/75) due to significant changes in nutrient levels during shipment of the samples from the field to the laboratory.

The reservoir data indicate nitrogen limitation at all stations and sampling times, with the exception of station 1 in October, i.e., the mean inorganic nitrogen/orthophosphorus ratios were 10/1 or less. However, the mean N/P ratio in October at station 1 was 15/1, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads at station A-2, in kg/km^2/year, and multiplying by the ZZ area in km^2.

The operator of the Sheridan wastewater treatment plant provided monthly effluent samples and corresponding flow data.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m³/d)	Receiving Water
Sheridan, WY	10,000	tr. filter	7,129.2	Goose Creek

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Tongue River	100,690	75.4
b. Minor tributaries & immediate drainage (non-point load) -	17,815	13.3
c. Known municipal STP's -		
Sheridan	14,775	11.1
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation** -	250	0.2
Total	133,530	100.0

2. Outputs -

Reservoir outlet - Tongue River 16,490

3. Net annual P accumulation - 117,040 kg.

* Treatment plant questionnaire.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Tongue River	504,485	76.4
b. Minor tributaries & immediate drainage (non-point load) -	90,445	13.7
c. Known municipal STP's -		
Sheridan	50,200	7.6
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	15,275	2.3
Total	660,405	100.0

2. Outputs -

Reservoir outlet - Tongue River 618,385

3. Net annual N accumulation - 42,020 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Tongue River	26	132

* See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Deer Creek	0.060	1.599
Squirrel Creek	0.127	1.719
Young's Creek	0.099	1.430

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	9.44	8.27	46.7	3.0

Vollenweider phosphorus loadings (g/m²/yr) based on mean depth and mean hydraulic retention time of Tongue River Reservoir:

"Dangerous" (eutrophic loading)	1.04
"Permissible" (oligotrophic loading)	0.52

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

[illegible]

LAKE CODE	LAKE NAME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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14	[illegible]	[illegible]	[illegible]
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APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

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[illegible]

APPENDIX D

PHYSICAL and CHEMICAL DATA

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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